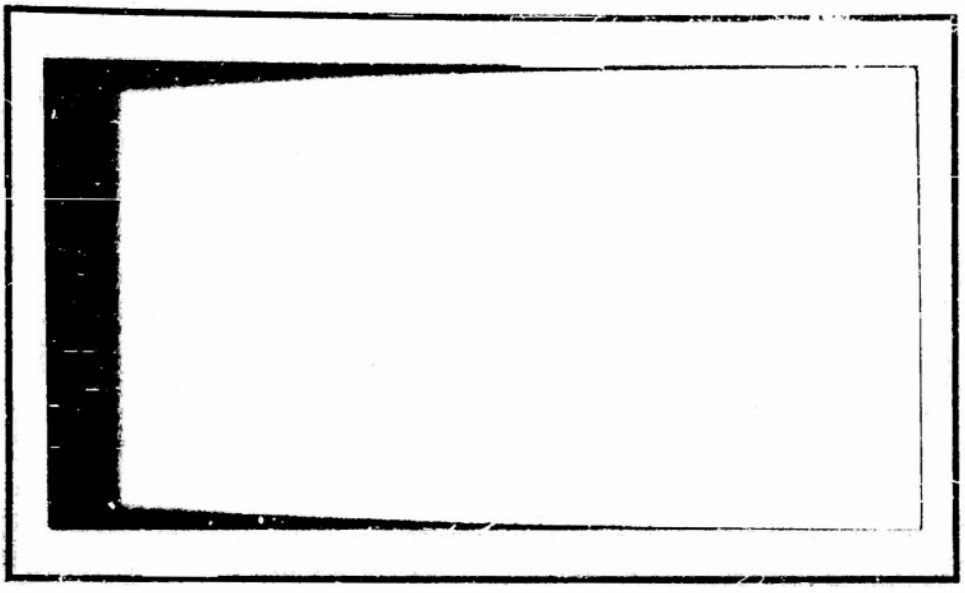

Microwave Laboratory
STANFORD UNIVERSITY
STANFORD, CALIFORNIA

INVESTIGATION OF HIGH-POWER KLYSTRONS

U. S. Navy Contract No. N6onr 25123
Code No. NR 073 361

STATUS REPORT

1 December, 1953 to 28 February, 1954

M. L. Report No. 238
May, 1954

Prepared by: The Staff of the
Microwave Laboratory

Approved by: E. L. Ginzton, Director
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Contract Noonr 25123
1 December, 1953 - 28 February, 1954

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(x) Part-time compensation during any or all of the period.
(+) Full-time compensation, entire period.

TECHNICIANS - MONTHS TOTAL FOR PERIOD

Electronics Technicians	4
Mechanicians	8
Tube Technicians	--
Drafting	--

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I. INTRODUCTION AND SUMMARY

The period covered by the present report is 1 December, 1953 to 28 February, 1954. The progress of the major projects is summarized in this section; the details are described in subsequent sections.

With the completion of the 1-Bev accelerator, most of the facilities available at the Microwave Laboratory have become congested because of the current emphasis on research in nuclear physics. The microwave group, and the personnel of this project in particular, has been dispersed into various buildings and laboratories. Recognizing the importance of the continuation of the work in the microwave field, the University has authorized the construction of a new Microwave Laboratory building in the immediate vicinity of the present accelerator building. The new building (15,000 sq ft in area) is nearing completion and will provide a new home for the Microwave Laboratory. The move to the new building will be carried out during the early summer months. The various projects supported by this contract will be largely concentrated in the new structure.

1. ACCELERATOR KLYSTRONS. Studies of the characteristics of accelerator klystrons, especially with regard to their life and the various causes of failure, are still continuing. Most of the work is being financed through the ONR-AEC accelerator contract (N6onr 25116), and some work pertaining to extensions to higher power and sealed-off versions is being financed by AEC Contract AT(04-3)-21 (Project Agreement No. 1). In addition to studying causes of failure, the accelerator klystrons are being continually improved by way of improving efficiency and power output.

The general improvement in the tubes during the last six months has been marked. It is now possible to operate as many as 18 or 19 klystrons simultaneously. The number of failures has been reduced to a very small number, and in the period of the present report none of these failures was due to window fractures. The average life of klystrons is now above 600 hours. Moreover, under the sponsorship of the AEC contract, it has become possible to seal off one of the accelerator klystrons. Although life data are not available, performance seems to be satisfactory at an output of 10 Mw. If this test is satisfactory, we shall have achieved one of our main goals.

As the accelerator klystrons continue to be used, more and more minor idiosyncrasies are being discovered. In some tubes, oscillations in the cathode-to-anode region have been observed, and if present completely spoil the operation of the tube. These oscillations will have to be studied further.

2. BASIC STUDIES. In an effort to improve the efficiency of klystrons, construction of models with better beam transmission has been attempted (as reported previously). These models also required modification of the middle cavity in order to suppress 5-cm oscillations which are present at the higher operating currents. Two additional klystrons of this improved variety have been completed and are now operating satisfactorily. The performance of these tubes has been described in a published contribution by J. H. Jasberg, of this Laboratory.*

As a part of the program to find methods of decreasing the operating voltages of klystrons, we have been carrying on a program of studying 'hollow-beam' electron guns. Further progress has been made with these tests, and the behavior of d-c and pulsed operation of the current model is now being reported.

The test of a klystron with a biased collector has been completed. It was hoped that suitable biasing of collector electrodes could substantially increase the efficiency. The tests just concluded show that a substantial improvement in efficiency is indeed possible, but is not nearly as high as had been hoped for. The method should be useful in tubes which employ large amounts of average power. The report on this study is now in preparation.

A study of the electrostatic-gradient focusing has been completed. This type of focusing, which was suggested by a similar configuration used in the 'strong-focusing' method on certain high-energy accelerators, might replace the heavy electromagnets generally employed to focus the beam of most high-power traveling-wave tubes. The scheme would be particularly useful in tubes whose structure lends itself to such a function.

3. PULSED TRAVELING WAVE TUBE. Tests are continuing with the 500-kw S-band pulsed traveling-wave tube. The results are very encouraging and will be described in the text.

Several new types of periodic structures have been examined; the best of these has been cold-tested and it is anticipated that a new tube with improved parameters will soon be built.

Calculations and measurements on cross-wound helices (which appear to have substantial merit for numerous applications) are being continued.

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* J. H. Jasberg, "Improvement of power output from pulsed klystrons," Proc. I.R.E., 42:859 (1954).

4. MILLIMETER-WAVE GENERATION. During the last two years, we have been conducting an experiment utilizing transverse acceleration of electrons. Although the 'undulator' principle of generating millimeter waves is the principal object of the study, the last year has been devoted to the construction of a small linear electron accelerator suitable for use with the undulator. The construction of this equipment has been nearly completed. It utilizes a buncher of the linear-electron-accelerator type, which will produce approximately 3 Mev when powered by a 1-Mw S-band magnetron. Several types of electron guns have been devised. One is of a klystron type using low-voltage injection, klystron-type bunching, and an acceleration in the 'catcher' cavity by means of an externally provided high-power source. Another gun uses field-emission techniques, and still another a more conventional 80-kv injection system. This equipment is currently being tested and is being made ready for resumption of millimeter-wave experiments.

II. ACCELERATOR KLYSTRONS (Staff: J. H. Jasberg)

The objective of this project is the study of high-power pulsed klystrons of the type that are used with the Stanford Mark III accelerator. The cost of construction and maintenance of these tubes is borne by the ONR-AEC Contract N6onr 25116. The progress of the research pertaining to these klystrons is reported here for the sake of completeness.

In this quarter, twelve tubes were added to the Mark III accelerator and two failed. The present complement is nineteen tubes. The two failures were due to a shorted heater and to a punctured main seal. The heater fault was caused by defective construction of the heater assembly. The punctured seal occurred after operation for some time partially under temperature-limited conditions. This was one of the old-type Housekeeper seals which is being replaced by the kovar type.

There have been no window failures on the accelerator this quarter. In spite of this record, there are some tubes which have become temperature-limited in use, but which are still usable on the machine. The reason for these partial failures is not yet known, but some investigation of trapping has been started to determine whether it is good enough to prevent pump oil from reaching the tube. Since all tubes have the same type of vacuum systems, it would be strange if imperfect trapping should prove to be the cause of failure. Some tubes have run more than 1000 hours (approximately one year at our present operation schedule) without failure of this type.

As a result of the success of two modified klystrons of the K-14 type (see below), the modifications are being added as fast as possible to the accelerator tubes.

No significant data have been discovered on the 12-cm cathode oscillation, which is found to occur to some extent in nearly all tubes. There is some evidence that this is absent or very low in tubes which have been modified (see below), although this information is limited to only two tubes. Investigation of the new modified tubes should give us more data in the next quarter.

III. BASIC STUDIES

A. SPECIAL KLYSTRON, K-14 (Staff: J. H. Jasberg)

The improvement of the klystron of the type used to power the Mark III accelerator is being carried out to a large extent on tubes of a special type, designated as the K-14 tube. This tube has the following modifications:

(a) Reamed throat at anode.
(b) Cathode moved 0.01 in. farther away from anode.
(c) 5-cm oscillation suppressors in middle cavity.

The tube continues to operate successfully on the Mark III accelerator with no evidence of old age. No additional tests have been carried out during the past quarter, since all tubes are needed on Mark III and because the processing station (which is also the test stand for these tubes) has not been available.

The other modified tube is operating on the Mark II accelerator, where it has been in use since May, 1953.

B. HOLLOW-BEAM STUDIES* (Staff: M. Chodorow, C. Susskind)

Tests of a hollow-beam electron gun have been resumed. It appears that a hollow beam can be obtained by means of a special cathode configuration, and maintained for some distance into the drift tube. This project is near completion; a technical report will be prepared.

C. REDUCED-VOLTAGE COLLECTOR (Staff: R. H. Winkler)

Tests were made on a two-cavity klystron with a special collector designed to recapture some fraction of the beam power following the r-f section of the tube. This is accomplished by slowing the electrons down with a retarding electric field produced by a segmented collector, the several segments being at a negative potential with respect to the drift tube.

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*This project is supported under Contract N6onr 25132.

A recovery of 24 per cent of the beam power was achieved, with the prospect of 30 per cent being easily achieved on future attempts. A report discussing the various aspects of this project is in preparation.

D. GRADIENT FOCUSING* (Staff: M. Chodorow, C.W. Barnes, Jr.)

The theory of electrostatic focusing has been revised, and it is now possible to get semi-quantitative agreement between the theory and experiment. The theory indicates that if the current is injected at just the right entrance conditions, then one can transmit 100 per cent of the current at relatively low focusing voltage. Under these circumstances there is a periodic ripple in the beam boundary at the periodicity of the focusing teeth. If the injection conditions are not quite right, and the actual tolerances on this are quite stringent, then in addition to the ripple there will be a low-frequency oscillation of the beam boundary which will result in loss of current. It is possible even under these circumstances to pass essentially all the current through, but much larger focusing voltages are required. Experiments apparently agree with these theoretical results. It has been also possible, by use of fluorescent material on the test structure, actually to determine roughly where the electrons are being lost. These results also agree with what the theory predicts.

A technical report is in preparation.

IV. PULSED TRAVELING-WAVE TUBE**

(Staff: M. Chodorow, E. J. Nalos, R. A. Craig, B. Arfin, E. L. Chu, J. E. Nevins, W. P. Ayers)

The existing r-f structure has been reassembled with new couplers. The tube is now on the vacuum pump and in the process of being tested. The r-f structure for a second tube with dimensions suitable for 100-kv operation has been partially completed, and cold tests have been made on this structure. A new type of loaded structure suitable for high-voltage operation has been tested. By suitable orientation of adjacent cavities and the use of slots which are properly placed, it is possible to get the microwave equivalent of negative mutual inductance. This results in a structure with a very wide pass band and positive phase velocity for the fundamental component. So far tests on one such structure have indicated

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* This project is supported under Contract N6onr 25132.

** This project is partially supported under Contract N6onr 25132.

a pass band of about 1000 Mc/s centered around 3000 Mc/s. Further tests will be made on this structure, including impedance measurements. Work on a modified interdigital structure is continuing and impedance measurements are being made with the intent to use this structure for pulsed operation with a high duty cycle at around 3 cm.

V. MILLIMETER-WAVE GENERATION

(Staff: H. Motz, W. Thon, R. N. Whitehurst)

The objective of this project is the generation of pulsed-microwave energy at millimetric wavelengths, notably by means of the "undulator," in which radiation takes place as a result of the acceleration of electrons by spatially periodic magnetic fields.

During the period under review, most of the construction work has been completed. Testing of the equipment will be initiated during the coming quarter. Some trouble was experienced with the L-cathode in the demountable system and a different gun construction might be necessary. An electroformed buncher section has been made available for this project and has been thoroughly tested at low power. The tests revealed loss and phase error in the structure. Both faults were diagnosed to be due to a loose disk, and it proved possible to remedy the fault by compression by means of an external steel clamp which could finally be removed.

Preliminary tests ofaa field-emission gun proved encouraging, although it has not yet been possible to check on its bunching properties. It is too early to say whether a number of ionic phenomena which were observed will interfere with successful operation of this type of gun.

A modification of the magnet structure of the undulator was designed and construction work on this is being started. The magnetron magnets previously used will be removed and replaced by electromagnets.

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